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Original Article

Performance of European system for cardiac operative risk evaluation in Veterans General Hospital Kaohsiung cardiac surgery

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Abstract

Background: The European System for Cardiac Operative Risk Evaluation (EuroSCORE) model is a widely-used risk prediction algorithm for in-hospital or 30-day mortality in adult cardiac surgery patients. Recent studies indicated that EuroSCORE tends to overpredict mortality. The aim of our study is to evaluate the validity of EuroSCORE in Veterans General Hospital Kaohsiung (VGHKS) cardiac surgery including a number of different surgical and risk subgroups.

Methods: From January 2006 to December 2009, 1,240 adult patients who underwent cardiac surgery in VGHKS were included in this study. The study was followed the guidelines of the Ethics Committee of Kaohsiung Veterans General Hospital, Taiwan. Both additive and logistic score of all patients were calculated depending on the formula in the official EuroSCORE website. The entire cohort, different surgical type and risk stratification subgroups were analyzed. Model discrimination was tested by determining the area under receiver operating characteristic (ROC) curve. Model calibration was tested by the Hosmer–Lemeshow chi-square test. Clinical performance of model was assessed by comparing the observed and predicted mortality rates.

Results: There were significant differences between the VGHKS and European cardiac surgical populations. The additive score and logistic score for the overall group were 7.16% and 12.88%, respectively. Observed mortality was 10.72% overall, 5.68% for isolated coronary artery bypass grafting (CABG), 4.67% for the mitral valve only and 4.25% for the aortic valve only group. The discriminative ability EuroSCORE was very good in all and various surgical subgroups, with area under the ROC curve from 0.75 to 0.87. The addictive and logistic models of EuroSCORE showed excellent accuracy, 0.839 and 0.845, respectively. Good calibration power was recognized by p value higher than 0.05 for the entire cohort and all subgroups of patients except for isolated CABG. The logistic EuroSCORE model overestimated mortality to different degrees in the various subgroups, indicating that the logistic EuroSCORE needs to be recalibrated by a factor about 0.55 for uncomplicated surgery and low-risk groups, and 0.85 for high-risk patients with original additive score more than six.

Conclusion: EuroSCORE is simple and easy to use. In the present study, the model demonstrated excellent accuracy in all and various surgical subgroups in VGHKS cardiovascular surgery populations. Good calibration ability in all and different risk categories was identified except for isolated CABG group. Recalibration factors of 0.55 and 0.85 were suggested for the various operative subgroups and risk categories.

Keywords: Cardiac surgery; EuroSCORE; Mortality; Risk score

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1. Introduction

The European System for Cardiac Operative Evaluation (EuroSCORE), developed beginning in 1995 in Europe, is a widely-used model to evaluate in-hospital or 30-day mortality in modern adult cardiac surgery patients. The additive EuroSCORE risk model was developed utilizing data of 17 risk factors for of 19,030 patients from 128 surgical centers in eight European states who underwent surgery between September and November 1995, and was published in 1999.[1,2] Subsequently, the logistic EuroSCORE model was developed to provide a better risk prediction, especially in high-risk patients and was published in 2003.[3] This model is as well the most widely-used risk prediction algorithm in Taiwan, owing in part to its validation with good results in Europe, North America and Japan,[4−7] and also its simplicity and bedside applicability during pre-operative consultation with patients.

To be utilized reliably outside the countries of origins, careful evaluation studies of the validity of the EuroSCORE model were carried out in different countries following its broad usage internationally. Several recent large national data collection studies held in Australia,[8] United Kingdom,[9] Italy,[10] China[11] and Germany[12] indicated that EuroSCORE tends to overpredict the mortality risk by analyzing the ratio between observed and expected deaths, which appears to be more marked for the logistic form of the model. Two meta-analysis studies also stated the same tendency of out-performing of the logistic model.[13,14] In Taiwan, a previously performed validative study of 801 consecutive adult cardiac surgical patients who underwent coronary artery bypass grafting (CABG) from one institution,[15] published in 2004, showed considerably relevant result between observed and expected mortality rates.

At present, the EuroSCORE is commonly used to identify potentially high-risk patients who are being considered for newly-developed transcatheter procedures such as trans-catheter aortic valve implantation (TAVI).[16] To recognize its fitness for Taiwanese cardiovascular surgical population, this study focused on the accuracy, calibration and clinical performance of the EuroSCORE in southern Taiwan, including a number of different surgical and risk subgroups.

2. Methods

2.1. Patients

From January 2006 to December 2009, 1,240 adult patients who underwent cardiac surgery with cardiac-pulmonary bypass or off-pump CABG in our institution (Veteran General Hospital Kaohsiung, Kaohsiung, Taiwan) were included in this study. The definitions of all risk factors were strictly according to the original publication of Nashef et al.[2] Both simple additive[1] and logistic EuroSCORE scores[3] of all patients were calculated depending on the formula in the official website (www.euroscore.org).

In addition to investigating the ability of the EuroSCORE for different surgical type and risk stratification, we further studied the performance in the following surgical subgroups: isolated CABG, isolated aortic valve surgery and isolated mitral valve surgery; and four risk categories grouped by additive score: low-risk (0−2), medium-risk (3−5), high-risk (6−13), and very high-risk (14+).

2.2. Statistical analysis

Statistical analysis was by unpaired t test for continuous variables and chi-square test for categorical variables. A p value under 0.05 was considered significant. Data analysis was performed using SPSS 10.5 statistical software package (SPSS Inc., Chicago, IL, USA). Data acquisition was performed using Microsoft Access version 2000.

Discrimination (statistical accuracy) was analyzed by calculating the area under the curve (AUC or c-index) of the receiver operating characteristic (ROC) curve.[17] The model was considered excellent if the area under ROC curve was >0.80, very good if >0.75 and good if >0.70. Calibration (statistical precision) was tested by using Hosmer−Lemeshow goodness-of-fit statistics, where the higher the p value was, the better the calibration of the model.[18] Clinical performance of the EuroSCORE model was assessed by comparing the observed and predicted mortality rates calculated by the logistic EuroSCORE according to the mean value with 95% confidence interval.

Multivariate logistic regression analysis was performed in the VGHKS patient population using the same variables according to the original publication of Rogues et al[3] in 2003. For age, $Xi = 1$ if patient age <60; Xi increases by one point per year thereafter (e.g. age 59 or less than $Xi = 1$; age 60 then $Xi = 2$; age 61 then $Xi = 3$ and so on).

3. Results

The prevalence of the risk factors in the two study populations are listed in Table 1. There were significant differences between the VGHKS and European cardiac surgical populations. Of the 1,240 patients, there were 133 in-hospital deaths observed, giving an overall observed mortality rate of 10.72% (9.09−12.62%). The additive score and logistic score for the overall group were 7.16% (5.76−8.71%) and 12.88% (11.11−14.92%), respectively.

Table 2 shows the predictive ability of the logistic EuroSCORE in the different surgical subgroups and risk categories. The values of area under the ROC curve were satisfactory for all and different types of cardiac surgery, ranging from 0.747 to 0.873, especially in isolated CABG patients group (AUC = 0.873). For all 1,240 patients, the addictive and logistic model of EuroSCORE showed excellent accuracy, with the values of area under the ROC curve 0.839 and 0.845, respectively (Fig. 1). Good model calibration ability, indicated by higher p values of the Hosmer−Lemeshow test, was demonstrated in all categories of patients except for isolated CABG.

The logistic EuroSCORE predicted a mortality that was higher than those observed for different operative subgroups and all risk categories. It means that the logistic EuroSCORE needs

Table 1
Prevalence of risk factors in the VGHKS and EuroSCORE populations

Risk factor	VGHKS prevalence (%)	EuroSCORE prevalence (%)	*p*
Number of patients (*n*)	1,240	19,030	
Age			
Mean ± SD	62.8 ± 13.87	62.5 ± 10.7	NS
Age group			
<60 (yr)	38.4	33.2	<0.001
60–64 (yr)	11.5	17.8	<0.001
65–69 (yr)	13.9	20.7	<0.001
70–74 (yr)	12.2	17.9	<0.001
75 + (yr)	24.1	9.6	<0.001
Sex, female	29.0	27.8	NS
Chronic pulmonary disease	2.0	3.9	<0.001
Extracardiac arteriopathy	4.4	11.3	<0.001
Neurological dysfunction	6.8	1.4	<0.001
Previous cardiac surgery	3.2	7.3	<0.001
Serum creatinine >200 mmol/L	17.0	1.8	<0.001
Critical pre-operative status	17.5	4.2	<0.001
Unstable angina	42.7	8.0	<0.001
LV dysfunction			
LVEF 30–50%	33.5	25.6	<0.001
LVEF <30%	7.7	5.8	<0.001
Recent myocardial infarction	24.0	9.7	<0.001
Pulmonary hypertension	8.4	2.0	<0.001
Emergency	11.5	4.9	<0.001
Other than isolated CABG	54.7	36.4	<0.001
Surgery on thoracic aorta	10.1	2.4	<0.001
Postinfarction septal rupture	0.6	0.2	<0.001

LVEF = left ventricular ejection fraction; NS = non-significant.

to be recalibrated by a factor of about 0.55 for uncomplicated surgery and low to medium-risk groups, and 0.85 for patients with original additive score more than six.[19]

Table 3 includes the values of the odds ratios and the values of β coefficients obtained by multivariate logistic regression analysis. For VGHKS cardiac surgical patients, having risk factors such as age, surgery on thoracic aorta, critical pre-operative status, LVEF<30%, surgery other than isolated CABG, poor renal function and emergency surgery indicated significantly greater risk of in-hospital mortality, ranging from 1.03 to 6.48. The β coefficients were estimated directly from VGHKS cardiac surgical patients (1,240 individuals) based on the same variables the original EuroSCORE database used.

4. Discussion

Accurate risk prediction models have assumed an important role in the practice of modern cardiovascular surgery and have proven invaluable in surgical decision making, pre-operative informed consent, quality assurance and healthcare management. Between the years of 1995 and 1999, 128 health centers throughout eight European countries worked to develop the European system for cardiac operative risk evaluation (EuroSCORE), with the aim of predicting 30-day mortality rates of patients undergoing cardiovascular surgery.[2] Risk scoring systems have reduced applicability when used in patient populations different from the ones they were formulated on. In recent years, several studies, including those using meta-analysis have stated that EuroSCORE is a good discriminative indicator, but tends to overpredict mortality,[8–14] particularly with regard to aortic valve surgery.[20–23]

These observations were not astonishing because the EuroSCORE model was developed in 15 years ago based on the patients who received cardiovascular surgery in 1995. There have been magnificent improvements in surgical techniques, anesthetic and perioperative intensive care quality, all of which have led to improved surgical results and a reduction in-hospital mortality. Furthermore, early mortality may increase significantly in the first several months versus that within the first month, especially in patients with comorbidity and postoperative complications, while the EuroSCORE now only observes the mortality within 30 days. The different definitions of outcome such as longer time-span result, patients who cannot discharge until end-day, and those who needed chronic respiratory care, might be considered.

Studies concerning the performance of EuroSCORE in Asian populations were rare. Nevertheless, the results were not as disappointing as those in Western populations, regardless of discrimination or calibration.[6,11,15,24,25] The results of various validation studies of EuroSCORE performed in different countries are summarized in Table 4.[5,6,8–12,15,25–27]

In Taiwan, Chen et al[15] reported an observed mortality rate of 10.6% in 801 adults patients who received primary or re-operative CABG, including both off- and on-pump CABG patients and those who underwent combined procedures during

Table 2
Predictive ability of logistic EuroSCORE for different subcategories of patients

	No. of patients	No. of death	Observed MR% (95%CI)	Predicted MR% (95%CI)	O/E	*p*[a]	AUC (95%CI)
All patients	1,240	133	10.72 (9.09–12.62)	12.88 (11.11–14.92)	0.83	0.087	0.845 (0.811–0.880)
Type of surgery							
Isolated CABG	563	32	5.68 (3.98–8.01)	10.7 (8.29–13.58)	0.53	0.007	0.873 (0.800–0.945)
Mitral valve only	150	7	4.67 (2.06–9.75)	8.5 (4.89–14.66)	0.55	0.393	0.747 (0.495–0.998)
Aortic valve only	94	4	4.25 (1.37–11.16)	7.63 (3.3–15.25)	0.56	0.374	0.856 (0.68–1.031)
Rank of risk[b]							
Low (0–2)	133	1	0.75 (0.04–4.74)	1.39 (0.26–5.87)	0.54	0.462	0.212 (0.14–0.284)
Medium (3–5)	370	7	1.89 (0.83–4.03)	3.12 (1.57–5.41)	0.60	0.587	0.605 (0.40–0.81)
High (6–13)	639	78	12.2 (9.82–15.06)	14.17 (11.67–17.25)	0.86	0.100	0.75 (0.70–0.80)
Very high (14+)	98	47	47.96 (37.85–58.2)	56.8 (46.75–67)	0.84	0.145	0.72 (0.622–0.821)

[a] The Hosmer–Lemeshow statistics.
[b] ranking by additive EuroSCORE.
AUC = area under the curve; CABG = coronary artery bypass grafting; CI = confidence interval; MR = mortality rate; O/E = observed/expected ratio.

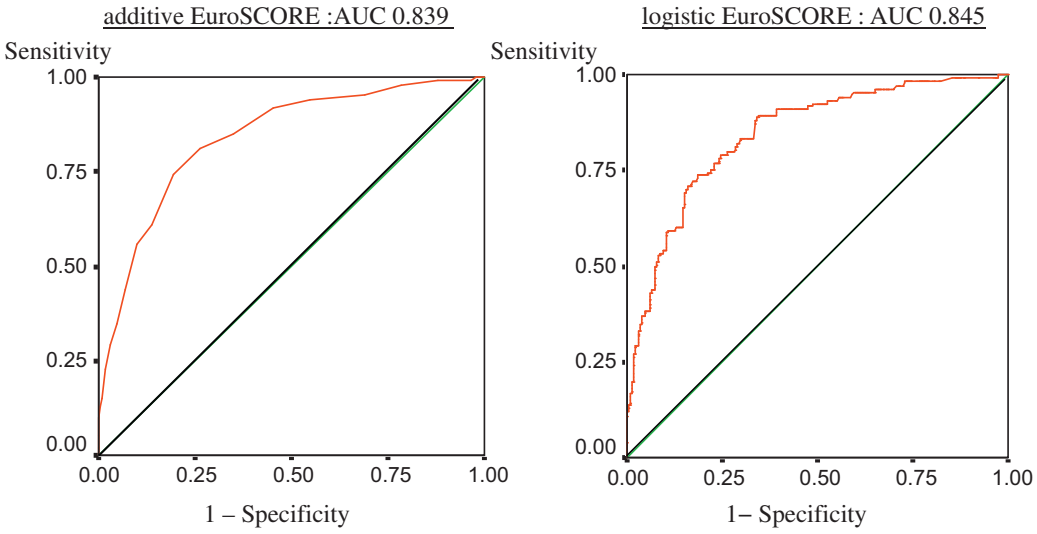

Fig. 1. Receiver operating characteristics curve of addictive and logistic model of EuroSCORE.

1999–2004. In our present study, 133 in-hospital deaths lead to an overall observed mortality rate of 10.72% (9.09–12.62%). Observed mortality rates were diverse in different surgical types, while the mortality rate of CABG with or without combined procedures was 8.21% (data not shown); indicating that despite the advancement of surgical devices and techniques, patients who received surgeries other than isolated CABG or isolated valve surgery are still with quite high-risk.

The logistic EuroSCORE demonstrated good discriminative ability in all and various surgical subgroups (AUC 0.75–0.87), compared with those from previous studies in different countries (AUC 0.64–0.9). The value of AUC indicates an ability of the model to differentiate between patients who died in-hospital or within 30 days from those who did not. Most studies, including the present one, demonstrated that the EuroSCORE model had powerful discriminatory ability (area under the ROC curve is >0.75). For modern adult cardiovascular surgeries, decision regarding therapeutic option (traditional open surgery or percutaneous intervention) has gradually become the leading issue of cost-benefit evaluation. Therefore, the EuroSCORE model as well may play an important role in identification of potentially high-risk patients for some minimally invasive procedures such as transcatheter aortic valve implantation, when an adequate cut-off point is defined by more reliable population-based studies.

Table 3
Multivariate association of EuroSCORE risk factors with observed mortality in VGHKS patient population. Ranking according to the OR

Rank	Risk factors	OR (95% CI)	β coefficient	*p*
	Age (continuous)	1.03 (1.00–1.06)	0.0259	0.0664
1	Surgery on thoracic aorta	6.48 (3.03–13.86)	1.8681	<0.0001
2	Critical pre-operative status	6.35 (3.79–10.62)	1.8476	<0.0001
3	LVEF <30%	5.59 (2.60–12.03)	1.7208	<0.0001
4	Other than isolated CABG	3.59 (1.82–7.09)	1.2791	0.0002
5	Serum creatinine >200 mmol/L	3.28 (1.95–5.51)	1.1874	<0.0001
6	Emergency	2.71 (1.51–4.86)	0.9966	0.0008
7	Recent myocardial infarction	1.96 (0.91–4.20)	0.6719	0.0848
8	Extracardiac arteriopathy	1.63 (0.60–4.42)	0.4881	0.3376
9	LVEF 30–50%	1.53 (0.80–2.93)	0.4260	0.1972
10	Neurological dysfunction	1.19 (0.53–2.65)	0.1732	0.6721
11	Pulmonary hypertension	1.13 (0.46–2.81)	0.1237	0.7897
12	Postinfarction septal rupture	1.05 (0.14–8.20)	0.0520	0.9604
13	Active endocarditis	0.98 (0.29–3.38)	−0.0171	0.9783
14	Female	0.78 (0.47–1.30)	−0.2448	0.3431
15	Unstable angina	0.73 (0.37–1.43)	−0.3174	0.3549
16	Previous cardiac surgery	0.66 (0.18–2.40)	−0.4175	0.5266
17	Chronic pulmonary disease	0.37 (0.04–3.40)	−0.9843	0.3821
	Constant βo		−5.2981	

CABG = coronary artery bypass grafting; CI = confidence interval; LVEF = left ventricular ejection fraction; OR = odds ratio.

Calibration tested by Hosmer–Lemeshow chi-square statistics was satisfactory in all categories of patients (*p* value 0.087–0.587) except for isolated CABG (*p* value 0.007). The reasons for this result are unclear and probably multi-factorial. The epidemiology of ischemic heart disease and comorbidity in Taiwan may be different from that of the European population. Better access to healthcare in a heavily government-assisted healthcare system, the National Health Insurance, which provided earlier, more aggressive investigation and higher quality medical care (e.g. use of statins), may also have contributed to the poor calibration performance of the EuroSCORE model for the isolated CABG patients group.

Clinical performance of the EuroSCORE model, assessed by comparing the observed and predicted mortality rates, was discussed mostly in previous studies because of general overestimation. The observed/expected ratio ranged broadly in different countries (O/E 0.32–1.56). In our study, the logistic model overpredicted mortality to different degrees in the various subgroups, ranging from 1.16 times for high-risk group, to 1.89 times for low-risk and uncomplicated surgery group. Differing case mixes of surgery type and risk category contributes variance of predicted mortality rate. General medication environment, health insurance policy and the habits of general population in

Table 4
Discrimination and calibration for the EuroSCORE in different countries

Author	Country	Surgery	Mode	No. of patient	Observed MR%	Predicted MR%	O/E	AUC	p[a]
Kawachi et al.[6]	Japan	All	ADDI	803	–	–	–	0.82	–
		CABG		301				0.89	
		valve		256				0.9	
Nashef et al.[5]	USA	All	ADDI	401,684	3.99	3.99	1.00	0.77	–
Bridgewater et al.[26]	United Kingdom	All	ADDI	8,572	1.70	3.00	0.57	0.75	–
Chen et al.[15]	Taiwan	CABG±	ADDI	801	10.60	11.83	0.90	0.75	–
			LOGI			11.80	0.90	0.74	
Yap et al.[8]	Australia	All	ADDI	8,331	3.20	5.31	0.60	0.83	<0.05
			LOGI			8.76	0.37	0.83	<0.05
		CABG	ADDI	5,592	2.00	4.25	0.47	0.82	<0.05
			LOGI			6.19	0.32	0.82	<0.05
Bhatti et al.[9]	United Kingdom	All	LOGI	9,995	3.30	5.70	0.58	0.79	–
		CABG		6,745	2.00	3.90	0.51	0.77	
		valve		1,523	3.50	7.90	0.44	0.79	
Au et al.[25]	Hong Kong	CABG	LOGI	1,247	2.90	4.00	0.73	0.76	0.903
		valve		1,406	4.80	5.20	0.92	0.77	0.803
D'Errigo et al.[10]	Italy	CABG	ADDI	30,610	2.54	2.54	1.00	0.77	0.228
			LOGI			6.27	0.40	0.78	<0.001
Zheng et al.[11]	China	CABG±	LOGI	9,248	3.27	5.51	0.59	0.72	–
		CABG		8,120	2.22	4.21	0.53	0.71	
Gummert et al.[12]	Germany	CABG	LOGI	26,501	2.60	5.18	0.50	0.77	–
		Aortic valve		6,305	3.90	7.28	0.53	0.69	
Wang et al.[27]	China	Valve	ADDI	1,726	4.46	3.51	1.27	0.64	0.204
			LOGI			2.85	1.56	0.65	0.038

[a] The Hosmer–Lemeshow statistics.
ADDI = additive; AUC = area under the curve; CABG = coronary artery bypass grafting; LOGI = logistic; MR = mortality rate; O/E = observed/expected ratio.

seeking medical resources varied from countries to countries may explain the wide range of observed/expected ratio.

In VGHKS cardiovascular surgical patients, multivariate logistic regression analysis revealed seven factors to be significant predictors of in-hospital mortality, including elder, critical pre-operative condition, emergent operation, surgery on thoracic aorta, other than isolated CABG, poor left ventricular ejection fraction and serum creatinine >2.26 mg/dL. On the contrary, patients with the factor of active endocarditis, female, unstable angina, previous cardiac surgery and COPD inversely predicted the risk of mortality, yet the associations were not statistically significant.

We have assessed the predictive ability of the EuroSCORE on cardiovascular surgery populations in the southern Taiwan, and have given useful contemporary calibration figures for the various operative subgroups and risk categories. However, the data was from single-institutional study, in which the number of patients who underwent isolated aortic valve surgery were few, while it is mainly focused on in recent studies. Furthermore, our data have not been validated externally, which is also a weakness of our study.

Although patients with severe left ventricular dysfunction had higher mortality and morbidity, CABG is recommended be done in these high-risk patients with acceptable results.[28] On the other hand, surgical repair of acute postinfarction ventricular septal defect with a endocardial patch and infarction exclusion method will improve the overall mortality.[29]

In conclusion, the EuroSCORE model demonstrated excellent accuracy in all and various surgical subgroups in VGHKS cardiovascular surgery populations. Good calibration ability in all and different risk categories was identified except for isolated CABG group. On the other hand, the model overpredicted mortality to different degrees at all risk levels; it means that the logistic EuroSCORE needs to be recalibrated by a factor of about 0.55 for uncomplicated surgery and low-risk to medium-risk groups, and 0.85 for high-risk patients with original additive score more than six.

Furthermore, our institution has participated in new data collection for EuroSCORE 2010,[30] broader physical and biological records, more detailed surgical definitions and different clinical outcomes were collected for this new model. The wider involvement of cardiovascular surgery population of various institutions in Taiwan, to evaluate the specific cardiovascular surgical risks for Taiwanese, will be the focus of future investigations.

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